Morphological and Phenological Comparisons of Two Hopi Maize Varieties Conserved In Situ and Ex Situ[1]

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Soleri, Daniela *(Office of Arid Land Studies, College of Agriculture, 845 North Park Avenue, University of Arizona, Tucson, Arizona 85719, dsoleri@ccit.arizona.edu) and* **Steven E. Smith** *(Department of Plant Sciences, College of Agriculture, Building #36, University of Arizona, Tucson, Arizona 85721, azalfalf@ccit.arizona.edu).* Morphological and Phenological Comparisons of Two Hopi Maize Varieties Conserved In Situ and Ex Situ. *Economic Botany 49(1):56–77. 1995. Over the last twenty-five years, crop genetic resources (CGR) have been preserved in genebanks around the world for use by formal plant breeders. Recently conservation of folk crop varieties for direct use by the farmer-breeders of traditional agricultural communities has been suggested as another purpose for CGR conservation. While both in and ex situ CGR conservation programs have been proposed to meet the needs of formal plant breeders and farming communities, the needs and goals of the two groups are different. Formal breeders seek maximum allelic diversity while farmer-breeders are interested in both diversity and population structure that provide local adaptation. Based on the morphological and phenological data analyzed for this study of two Hopi maize varieties conserved in and ex situ, it appears that both genetic shift and genetic drift have occurred ex situ, and that populations conserved ex situ are different from those maintained in situ. These findings suggest that CGR conservation strategies must be re-evaluated in light of the specific conservation goals that are sought.*

Comparaciones Morfologicas y Fenologicas de Dos Variedades de Maiz Hopi Conservadas In Situ y Ex Situ. *Durante los pasados veinticinco años, los recursos geneticos agricolas (RGA) han sido preservados en bancos de germoplasma alrededor del mundo para su uso por fitomejadores formales. Recientamente, la conservacion de variedades crillolas para su uso directo por agricultores-fitomejsdores de las comunidades agricolas tradicionales se ha sugerido como otro de los propositos para la conservacion de recursos geneticos. Mientras que los programas de conservacion de RGA in situ y ex situ han sido propuestos para satisfacer las necesidades de fitomejoradores formales y cominidades agricolas, las necesidades y objetivos de los dos grupos son diferentes. Los fitomejoradores formales buscan la maxima diversidad genetica, mientras que los agricultores-fitomejoradores estan interesados en diversidad y estructura poblacionalque permita mayor adaptacion local. En bas a datos morfologicos y fenologicos analizados en este estudio de dos variedades de maiz Hopi conservadas in situ y ex situ, al parecer, la conservacion ex situ ha producido seleccion natural (genetic shift) y perdida aleatoria de diversidad (genetic drift), asimismo, parece que la poblaciones conservadas ex situ difieren de las conservadas in situ. Estos resultados sugieren que las estrategias para las conservacion de RGA deben ser re-evaluadas conforme a los propositos especificos de conservacion.*

Key words: crop genetic resources; in situ and ex situ conservation; *Zea mays*; Hopi Native Americans.

Over the past twenty-five years there has been a tremendous effort to preserve crop genetic resources (CGR) in genebanks around the world. Conservation has focused largely on collection and preservation of CGR ex situ in genebanks primarily for use as raw material in the development of modern varieties for large-scale, capital intensive agriculture, referred to here as industrial agriculture (Cohen et al. 1991). The hope has been that accessions of seed-propagated species could be kept viable in genebanks, periodically regenerated and evaluated, thus replenishing the base collecting and providing material for

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Velasquez, and Santana Michel 1990). Gene flow may also ultimately reduce genetic diversity. For ex situ conservation of genetic diversity, the concern is that the foreign alleles or genotypes may have greater selective advantage than those in the original population, eventually eliminating them, potentially decreasing genetic diversity. In the ex situ environment excluding foreign pollen is labor intensive and contamination from conspecific populations in the vicinity is possible.

Entire populations or varieties may also be lost during conservation. For example, deterioration of seed viability resulting from storage or regeneration conditions can result in the loss of ex situ collections (e.g., Plucknett et al. 1987:79–82; Roos 1984b).

Loss of varieties in situ may also occur as sociocultural, economic, and environmental changes affect traditional agriculture. Although the assumption that folk varieties would be completely replaced by modern varieties has not proven correct, the effect of modern variety introduction on the genetic structure of folk varieties has not been investigated and may be significant (Friis-Hansen 1993; Hodgkin, Rao, and Riley 1993; Soleri and Cleveland 1993).

Purpose of This Study

The purpose of our study was to investigate the effects of conserving two Hopi maize folk varieties ex situ in a national germplasm program and in situ by Hopi farmers. We tested three hypotheses: 1) ex situ conservation of populations of a maize folk variety results in significant changes to those populations; 2) there are no significant differences between populations of a maize folk variety maintained by Hopi farmers today; and 3) there are significant differences between a folk variety maintained in situ by farming households today and the same folk variety maintained ex situ by an institutional conservation program. The first hypothesis is concerned with change occurring during the conservation process, while the last two investigate differences that may be the result of change but cannot necessarily be attributed to it based on the evidence available in this study. In testing these hypotheses our goal was to better understand the effects of in and ex situ conservation and the implication of these two conservation strategies for meeting the needs of formal plant breeders, and especially the farmer-breeders of traditional farming communities.

Hopi Agriculture and Maize

The Hopi Native American homeland in northern Arizona has a relatively short but warm frost-free season (120–160 days) with an approximate average total of 3403 growing degree days (GDD) between May 1–October 31 [Calculated using the 50-86°F base temperature range as described in Wisner (1972). Based on the only years of complete temperature data available for Tuba City, AZ (1951, 1952, 1973, 1974, 1988, 1989)]. The average annual precipitation of 15–23 cm falls as rain and snow January to April, and as summer rains mid-July to mid-September. In addition, drying winds early in the growing season, and high rates of evapotranspiration make water a limiting factor for crop production (Prevost, Ahrens, and Kriz 1984). Despite these difficulties, a majority of Hopi households continue to farm and/or garden. Maize, beans (*Phaseolus vulgaris* L., *P. acutifolius* Gray var. *latifolius* Freem., *P. lunatus* L.), squash (*Cucurbita argyrosperma* Pang, *C. maxima* Duch. ex Lam.) and melons (*Cucumis melo* L., *Citrullus vulgaris* Schrad.) are grown without irrigation in fields composed of a sand layer over loam in alluvial fans, loam soils in seasonal waterways, or sand soils in dunes often located over seeps (Hack 1942:36).

Maize (Fig. 1) is the most widely grown crop in Hopi agriculture and has a central place in Hopi social and religious life (Frigout 1979). Traditionally, in late spring as soil temperatures rise and soil moisture recedes, maize kernels are sown by hand more than 25 cm below the surface to the moist underlying soil. There is evidence that Hopi and Navajo folk varieties are uniquely adapted to this environment and planting practice (Bradfield 1971; Collins 1914a; 1914b). Today many Hopi farmers plant with tractors, though often with equipment they have built specifically for deep sowing. Irrigation, fertilizers, and other agrochemicals are rarely used in maize production.

In a survey conducted in 1989 for Native Seeds/SEARCH of Tucson, Arizona, 50 Hopi households grew a total of 17 Hopi maize folk varieties (as defined by the farmers themselves) with an average of 6 maize varieties in each household (Soleri and Cleveland 1993). Most commonly

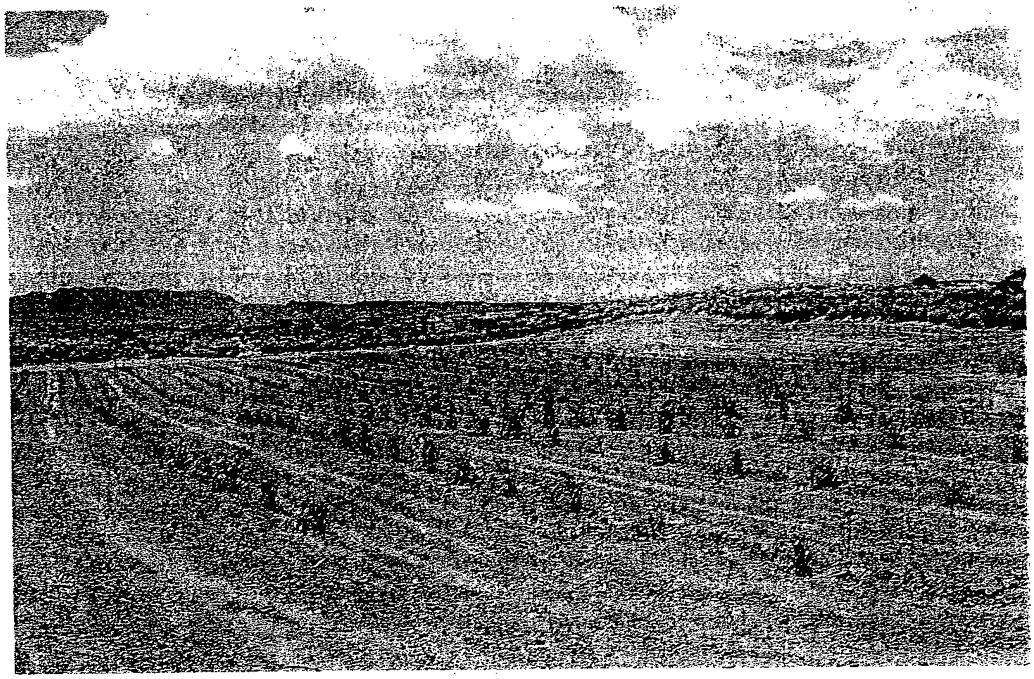

Fig. 1. Hopi blue maize field in mid summer. Photographed with permission. D. Soleri.

grown were Hopi blue and Hopi white field maize; sweet corn was the only variety for which some farmers commonly used commercial cultivars.

USDA/ARS NPGS MAIZE COLLECTION

The USDA/ARS NPGS (US Department of Agriculture/Agricultural Research Service National Plant Germplasm System) active maize germplasm collection containing 12 500 accessions (M. Millard, personal communication 1992) is maintained at the North Central Regional Plant Introduction Station (NCRPIS) in Ames, Iowa. The average frost-free season is 150–160 days, with an average total of 2853 GDD [50–86°F base temperature range as in Wisner (1972), based on data from 1951–1991] between May 1 and October 31 (Iowa State University Climatology Records, Ames, IA; S. E. Taylor, personal communication 1994). Of the average 80 cm of annual precipitation, more than 75% falls during the growing season (May–October) (Iowa State Climatologist, Des Moines, IA, personal communication 1994). Should rainfall during the growing season be inadequate, NCRPIS plantings receive supplemental irrigation. The NCRPIS follows the standard regional recommendations for application of agrochemicals to their soils and plants.

The national maize germplasm collection began in 1948 when the NCRPIS was established. Early conservation techniques included regeneration in hills, and later in rows, and hand pollination with bulked pollen for seed production. Kernels were then bulked, and samples taken for both the active collection for distribution and conservation at NCRPIS, and the base collection for conservation and future regeneration. Starting in 1988 this protocol was revised through the use of perfect sampling (P. Bretting and M. Millard, personal communication 1994), to maximize survival and representation of all genotypes in the population, and minimize the genetic shifts reported for other collections of cross-pollinated crop species (Burton 1976). Regeneration of accessions held in the maize collection is done as needed, determined by germination rates (maintained at ≥85%) and amount of kernels on hand (North Central Regional Plant Introduction Station 1993:46). Kernels are planted in rows, with the goal of obtaining 200 plants per accession. Pollination is by a modified chain cross, in which pollen from one plant pollinates a different, randomly chosen plant, with each plant producing